Diversity, abundance and distribution of seagrasses in three community fisheries, Kampot Province, Cambodia

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មូលន័យសង្ខេប

ស្មៅសមុទ្របានផ្តល់នូវសេវាកម្មអេកូឡូស៊ីដ៏មានសារៈសំខាន់ចំពោះតំបន់ឆ្នេរនៅជុំវិញពិភពលោក ដោយវាដើរតួជាជម្រកសម្រាប់ការបន្តពូជ ព្រមទាំងរួមចំណែកក្នុងការការពារតំបន់ឆ្នេរ និងស្តុកកាបូន។ ទោះបីជា ប្រទេសកម្ពុជាជាប្រទេសដែលមានគម្របស្មៅសមុទ្រជាប់ចំណាត់ថ្នាក់ខ្ពស់ក្នុងចំណោមបណ្តាលប្រទេសនៃតំបន់អាស៊ីអាគ្នេយ៍ក៏ដោយ ប៉ុន្តែការស្រាវជ្រាវទៅលើស្មៅសមុទ្រនៅមានកម្រិតតិចតួច។ ទោះបីជាស្មៅសមុទ្រត្រូវបានរងការខូចខាត ដោយសារសកម្មភាពអភិវឌ្ឍន៍តំបន់ឆ្នេរ និងសកម្មភាពនេសាទខុសច្បាប់ជាប្រវត្តិសាស្ត្រ ស្មៅសមុទ្រដែលមានទំហំធំ និងចម្រុះប្រភេទមានវត្តមាននៅតំបន់ឆ្នេរខេត្តកំពត។ យើងបានធ្វើការវាយតម្លៃភាពចម្រុះនៃប្រភេទ ចំនួនឯកត្ត: និងការកំណត់របាយស្មៅសមុទ្រនៅក្នុងដែនសហគមន៍នេសាទចំនួនបីក្នុងខេត្តកំពត រួមមានសហគមន៍នេសាទត្រពាំងរពៅ សហគមន៍នេសាទព្រែកខ្នោត និងសហគមន៍នេសាទចង្ហោន។ ប្រភេទស្មៅសមុទ្រ និងភាគរយរបស់វាត្រូវបានកត់ត្រានៅក្នុងក្វាដ្រាតដែលបានដាក់នៅតំបន់ទឹកជោរនាច ដោយប្រើខ្សែម៉ែត្រដើម្បីកំណត់របាយស្មៅសមុទ្រនៅក្នុងតំបន់ទាំងនោះ។ ជាលទ្ធផលនៅក្នុងតំបន់ដែលបានសិក្សា ស្មៅសមុទ្រចំនួនប្រាំបីប្រភេទត្រូវបានកត់ត្រា ដែលគ្របដណ្តប់លើក្រឡាផ្ទៃចំនួន១,៤៨៨ហិកតា និងមានភាគរយជាមធ្យម២៨.២% នៅក្នុងដែនសហគមន៍នេសាទត្រពាំងរពៅ ៤៦.៥%នៅក្នុងដែនសហគមន៍នេសាទព្រែកខ្នោត និងប្រមាណជា៤២.៥%នៅក្នុងដែនសហគមន៍នេសាទចង្ហោន។ ការរកឃើញនេះ បានគូសបញ្ជាក់ពីសារៈសំខាន់នៃអេកូឡូស៊ីជម្រកស្មៅសមុទ្រ និងផ្តល់នូវមូលដ្ឋានគ្រឹះសម្រាប់ការត្រួតពិនិត្យ និងការអភិរក្សដែនសហគមន៍នេសាទនៅក្នុងខេត្តកំពត។ ការអភិរក្សជម្រកស្មៅសមុទ្រមានសារៈសំខាន់ ដើម្បីទ្រទ្រង់ជីវៈចម្រុះ សេវាកម្មប្រព័ន្ធអេកូឡូស៊ី និងជីវភាពរស់នៅក្នុងតំបន់ ដោយផ្អែកលើវិស័យទេសចរណ៍ និងការនេសាទនៅតំបន់ឆ្នេរសមុទ្រនៃប្រទេសកម្ពុជា។

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Abstract

Seagrasses provide important ecosystem services in coastal regions worldwide, acting as nursery habitats and contributing to shoreline protection and carbon sequestration. Although Cambodia ranks highly among Southeast Asian countries for seagrass cover, research in the country has been limited. Large seagrass meadows with high species diversity historically occurred in coastal areas of Kampot Province, although these have been degraded by coastal development and illegal fishing practices. We evaluated the species diversity, abundance and distribution of seagrasses in three community fishery areas within the province (Trapang Ropov, Preaek Tnaot & Chang Houn). Species and percentage cover were recorded in quadrats placed along intertidal transect lines to determine the distribution of seagrasses in these areas. Eight seagrass species were recorded and seagrass meadows covered 1,488 ha within the study area, with an average cover of 28.2% in Trapang Ropov, 46.5% in Preaek Tnaot and 42.5% in Chang Houn. Our findings highlight the ecological significance of seagrass habitats and provide a baseline for monitoring and conservation of community fisheries in Kampot Province. Conservation of seagrass habitats is essential to sustain biodiversity, ecosystem services and local livelihoods based on tourism and fishing in coastal Cambodia.

Keywords Abundance, distribution, diversity, seagrass, community fisheries, Cambodia

Introduction

Seagrasses are marine angiosperms that provide vital ecosystem services in coastal regions worldwide (Duarte *et al*., 2008). Southeast Asia has the greatest diversity of seagrass species and habitat types globally (Fortes *et al*., 2018) and many coastal communities in the region depend on seagrass meadows for their livelihoods and food security (Unsworth *et al*., 2010). These meadows deliver essential services by sustaining marine fisheries and biodiversity, protecting coastlines and providing tourism opportunities (Ouk *et al*., 2010).

Cambodia ranks among the top countries in Southeast Asia for seagrass coverage and seagrass meadows accounted for over 6% of Cambodian waters in 2008 (Fortes *et al*., 2018). The shallow waters of the Kampot and Kep provinces historically supported some of the most extensive meadows in the region (UNEP, 2008; Supkong & Bourne, 2014). However, recent assessments suggest these declined significantly from an estimated 32,492 ha in 2008 to just 13,830 ha in 2023 across the kingdom's four coastal provinces (FiA, 2023a). Despite this, seagrass research remains limited in the country (Fortes *et al*., 2018).

The first largescale assessment of seagrasses in Kampot Province documented 12 species (Ouk *et al*., 2010), whereas a mapping survey in 2013 estimated seagrass coverage at 8,435.8 ha (Supkong & Bourne, 2014). More recent data indicate seagrass coverage has declined to 5,158 ha in Kampot and 6,399 ha in Kep province (FiA, 2023a). Seagrass meadows in Cambodia are threatened by land reclamation, pollution, coastal development (Supkong & Bourne, 2014) and illegal fishing practices such as trawling, gillnets, and motorised push nets (Cockerell *et al*., 2016). Seagrass meadows in Kampot Province particularly have been substantially degraded by industrial port development and associated land reclamation, alongside illegal bottom-trawling (WEA & MCC, 2020). These activities degrade water quality and clarity, thereby reducing the photosynthetic efficiency of the seagrass (Duarte, 2009; Duarte *et al*., 2008; Unsworth *et al*., 2024). The loss of seagrass meadows threatens the overall function of coastal ecosystems (Waycott *et al*., 2009) and compromises fisheries and food security (Unsworth *et al*., 2018). This is because seagrasses meadows provide shelter and nursery grounds for many marine species (Nordlund *et al*., 2018) and serve as a primary food source for macrograzers such as green sea turtles and dugongs and micrograzers such as sea urchins (Di Carlo & McKenzie, 2011).

Community Fisheries (CFIs) are a form of locally managed marine area in Cambodia which fall under the jurisdiction of the Ministry of Agriculture, Forestry and Fisheries (RGC, 2006). These are managed by groups of small-scale fishers who are granted co-management and resource use rights in their local fishing grounds, including delineation of boundaries and permissible fishing practices (RGC, 2007). Remaining seagrass beds in Kampot Province are largely confined to CFIs and particularly areas with passive anti-trawling measures such as submerged concrete blocks and demarcation poles (WEA & MCC, 2020). The aim of our study was to determine the diversity, abundance and distribution of seagrass in three CFIs in Kampot Province. These are located within a proposed Marine Fishery Management Area, a larger form of protected area in Cambodia which

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is co-managed by the CFIs and the Fisheries Administration under MAFF. Our assessment was undertaken to provide a baseline for monitoring the effectiveness of conservation interventions within the CFIs on seagrass diversity, abundance and distribution.

Methods

Study site

Our study was conducted between June and November 2021 in three adjacent CFIs in Kampot Province: Trapang Ropov (10°35′07.17″N, 103°55′39.04″E), Preaek Tnaot (10°34′58.26″N, 103°57′19.49″E) and Chang Houn (10°34′38.32″N, 103°58′43.16″E) (Fig. 1). Spanning a total area of 3,923 ha, the three CFIs were proposed in 2001 (FiA, 2021) and formally registered by MAFF in March 2011. We selected these areas for study due to their protection as CFI areas and location within a proposed Marine Fisheries Management Area. Additionally, the CFIs play an important role in protecting seagrass habitats and maintaining ecosystem diversity within the province.

Trapang Ropov CFI encompasses 1,251 ha and is situated between the Trapang Ropov and Preaek Tnaot rivers, where 315 ha of seagrass were previously recorded (FiA, 2011c). To the east of the Preaek Tnaot River, the Preaek Tnaot CFI spans 1,168 ha (FiA, 2011b). The Chang Houn CFI covers 1,504 ha, with 400 ha of seagrass previously documented (FiA, 2011a). These areas were evaluated Among seven CFIs in Kampot Province, these three were regarded as having high management effectiveness, institutional sustainability, committee performance and ecological impact (FiA, 2023a).

Data collection

The diversity and abundance of seagrasses in each CFI was assessed using the intertidal fixed transect sites methodology (McKenzie *et al*., 2003). Transects were located based on the distribution of seagrasses, areas of high species diversity, and site accessibility. Within each CFI, three 50 m transects spaced 25 m apart were established perpendicular to the shoreline in waters less than 1.5 m depth (McKenzie *et al*., 2001). Because seagrasses in the three CFIs occurred in intertidal and subtidal zones,

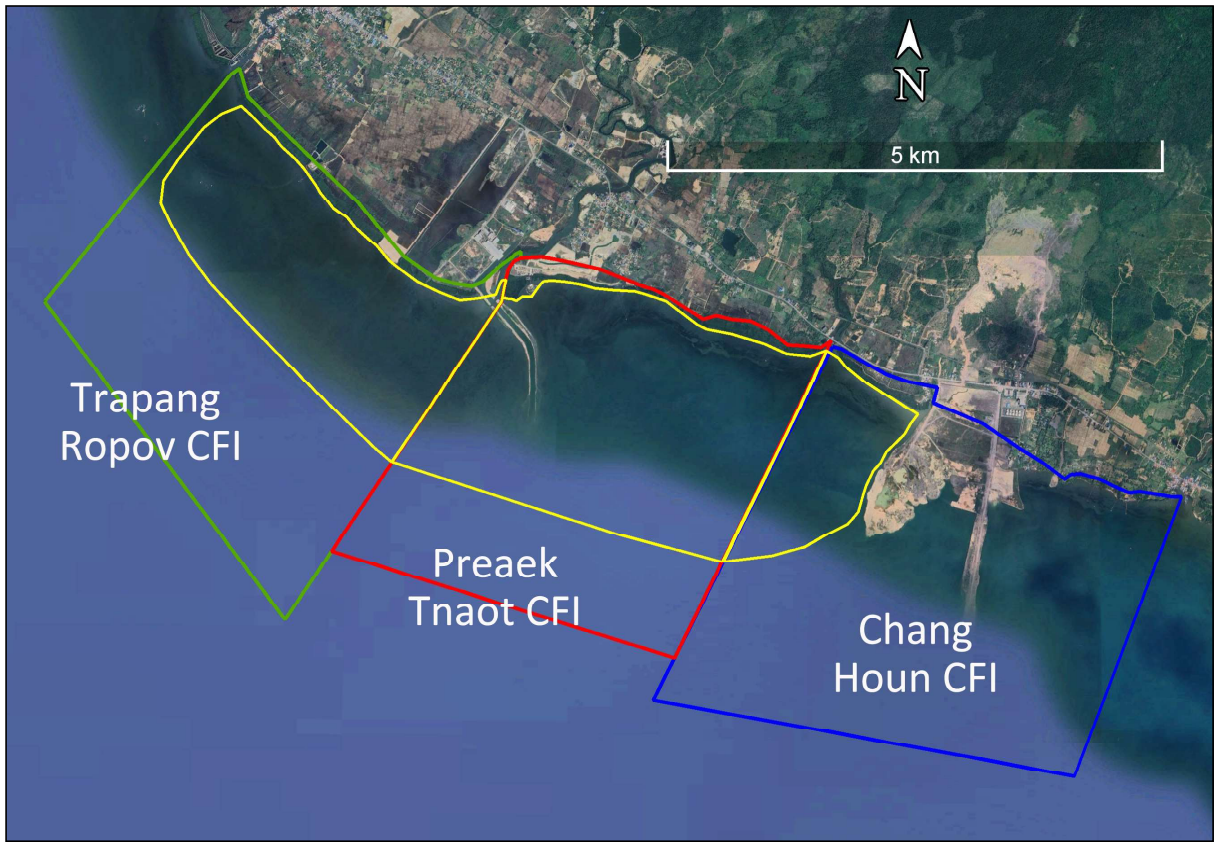


Fig. 1 Community fisheries (CFIs) and seagrass meadows (yellow boundary) studied in Kampot Province, Cambodia

our surveys required walking the transects during low tide and snorkelling in deeper sections.

Our survey area overlapped with previous studies (UNEP, 2008; Ouk *et al*., 2010) that mapped the extent of seagrasses along the Kampot coastline. We used a hand-held GPS unit (GPSMAP 64s, Garmin, Kansas, USA) to locate and record the location of each transect, and surface marker buoys were dropped to mark the start and end of these. Transects were deployed via swimming or walking using a compass for orientation.

Three transects were surveyed in each CFI, giving a study total of nine transects. Quadrats (0.25 m^2) were placed at five metre intervals along each transect to identify seagrass species and estimate their percentage cover. The species identification and percentage cover calculation guidelines of McKenzie *et al*. (2003) were followed to ensure consistency. As potential indicators of environmental conditions such as nutrient enrichment, the percentage cover of benthic algae and epiphytic algae on seagrass leaves was also recorded. Water depth and substrate types were recorded for each quadrat.

The spatial distribution of seagrass in the three CFIs was documented using spot-checks undertaken along line transects spaced at 400 m intervals along the coastline. The presence or absence of seagrass was recorded at 200 m intervals along these transects, which extended offshore from shallow to deeper waters (McKenzie, 2003). This approach allowed the team to document seagrass distribution within the wider CFI areas, beyond the parts surveyed using quadrats.

Table 1 Seagrass species recorded in Community Fisheries in Kampot Province (x = present inside quadrats, + = present outside quadrats)

Species	Trapang Ropov	Preaek Tnaot	Chang Houn
Hydrocharitaceae			
Enhalus acoroides	x	x	x
Thalassia hemprichii	x	x	x
Halophila ovalis	+	+	+
Cymodocea serrulata	+	x	x
Cymodocea rotundata	x	x	x
Cymodoceaceae			
Halodule pinifolia	+	x	+
Halodule uninervis	+	x	x
Syringodium isoetifolium		x	x

Data analysis

Data were analysed in *R* software vrs. 4.4.0 (R CoreTeam, 2024). Species richness and relative abundance measures were used to quantify the seagrass flora at our study sites. Box and whisker plots were created using the *ggplot2* package and *geom_boxplot()* function (Barber, 2023) to visualise variations in seagrass species richness, percentage cover, and the relative abundance of benthic algae and epiphytic algae in the three CFIs. The Kruskal-Wallis test was employed to test for significant differences between the three CFIs, using *tidyverse* package (Borcard *et al*., 2011) in *R*. *ArcGIS* software (ERSI, California, USA) was used to map the distibution of seagrasses based on the data generated by spot-checks.

Results

Eight seagrass species arranged in two families (Hydrocharitaceae & Cymodoceaceae) were recorded in the Trapang Ropov, Preaek Tnaot and Chang Houn CFIs (Table 1). These included seven species documented within our quadrats, and one which was only observed outside of these (*Halophila ovalis*). All eight species were recorded in the Preaek Tnaot and Chang Houn CFIs, whereas only seven species were documented in the Trapang Ropov CFI (Table 1, Fig. 1).

Average species richness within the quadrats differed significantly between the three CFIs (Kruskal-Wallis, p=5.4^{e-06}) (Fig. 2). Preaek Tnaot had the highest species richness within the quadrats surveyed with seven species, followed by Chang Houn with six species. Only three species were observed within quadrats in Trapang Ropov. Mean cover of seagrass within quadrats was highest in Preaek Tnaot (46.5%), followed by Chang Houn (42.5%) and Trapang Ropov (28.2%). The relative abundance of seagrass differed significantly between CFI (Kruskal-Wallis, p=3.5^{e-07}) (Fig. 3).

The relative abundance of different seagrass species also varied by CFI (Fig. 4). In Trapang Ropov, *Thalassia hemprichii* was most abundant, alongside *Enhalus acoroides* and *Cymodocea rotundata*. In Chang Houn, *C. rotundata* was the dominant species, followed by *T. hemprichii* and *Cymodocea serrulata*. In Preaek Tnaot, *Syringodium isoetifolium* was the most abundant species followed by *T. hemprichii* and *C. rotundata*. Overall, *T. hemprichii* was most abundant across all three CFIs, followed by *C. rotundata*, *E. acoroides*, *S. isoetifolium*, *C. serrulata* and *Halodule uninervis*. The least common species was *H. pinifolia*.

Seagrass meadows covered a total of 1,488 ha across the three CFIs, with 544 ha in Trapang Ropov, 756 ha in

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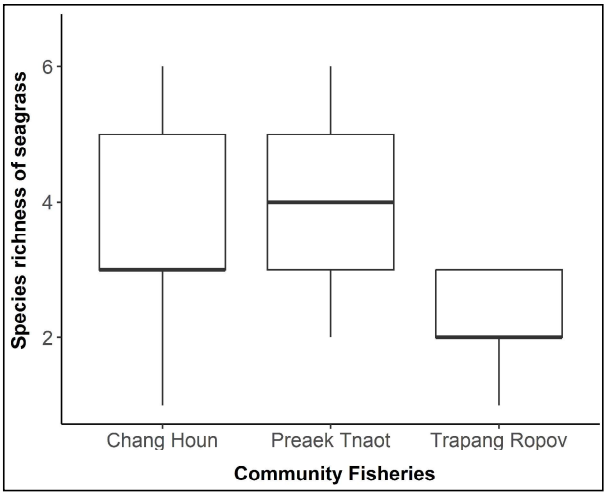


Fig. 2 Box and whisker plots of seagrass species richness in three community fisheries in Kampot Province

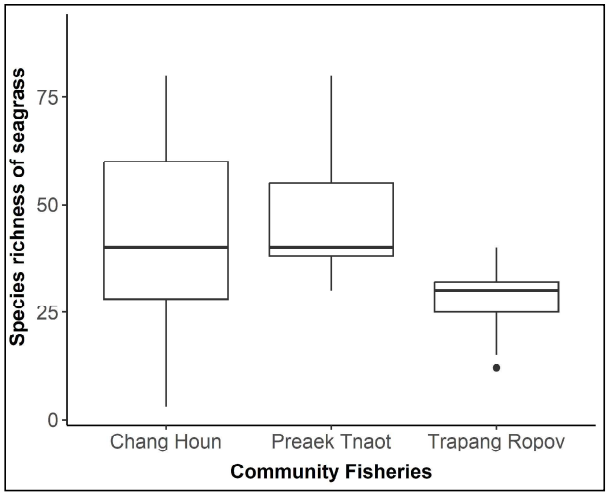


Fig. 3 Box and whisker plots showing relative abundance of seagrasses in three community fisheries in Kampot Province

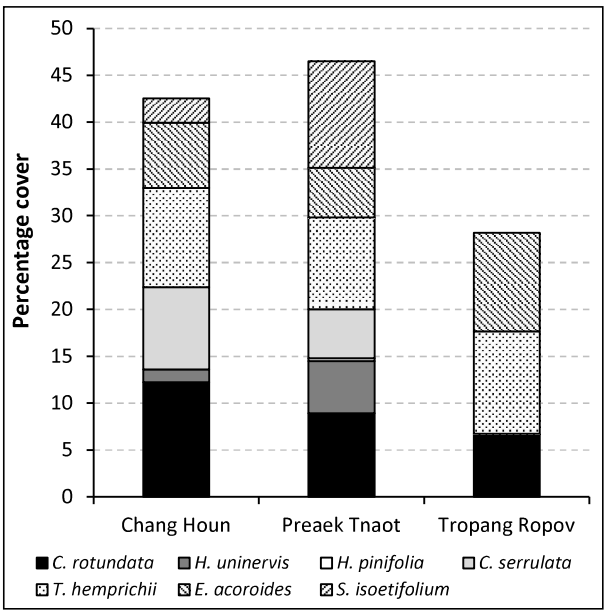


Fig. 4 Relative cover of seagrass species richness in three community fisheries in Kampot Province

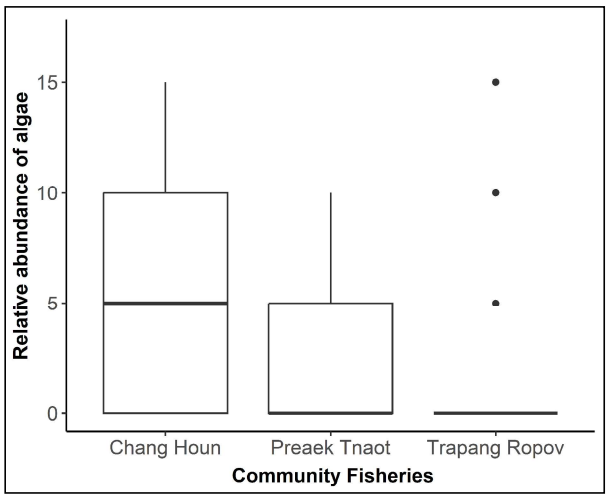


Fig. 5 Box and whisker plots showing relative abundance of benthic algae in three community fisheries in Kampot Province

Preaek Tnaot and 188 ha in Chang Houn (Fig. 1). Benthic algae were highest in Chang Houn and lowest in Trapang Ropov (Fig. 5). These differences were statistically significant (Kruskal-Wallis, p=0.00067). Epiphytic algae cover also differed significantly between the CFIs (Kruskal-Wallis, p=6.5^{e-05}), with the highest cover in Preaek Tnaot, followed by Chang Houn and Trapang Ropov (Fig. 6). Substrates across the three CFIs comprised coarse sand (42%), sand (30%), fine sand (21%) and rubble (7%).

Discussion

Our results provide a valuable baseline for monitoring efforts and may have implications for future conservation interventions in Kampot Province.

We recorded eight seagrass species, somewhat fewer than previously documented within the province. For instance, Ouk *et al*. (2010) recorded 12 species, whereas Supkong & Bourne (2014) documented 11 species, and FiA (2023a) recorded ten species. Higher species richness has also been recorded in Kep province by Reid *et al.* (2019) and Coals *et al*. (2019) who recorded nine and ten

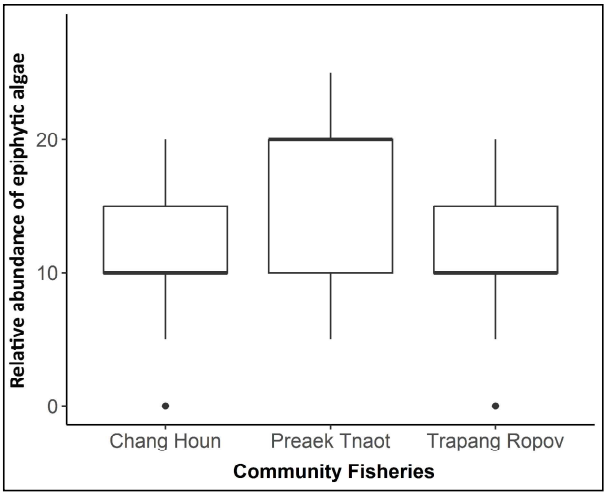


Fig. 6 Box and whisker plots showing relative abundance of epiphytic algae in three community fisheries in Kampot Province

species, respectively. The lower diversity we observed may be attributable to the relatively small area sampled in shallow intertidal zones (maximum depth of 1.5 m). Factoring in water depth, our results are closer to Ouk *et al*. (2010) who recorded six species in similarly shallow waters in Kampot province, including one species we did not observe: *Halophila decipiens*.

We recorded eight seagrass species in the Preaek Tnaot and Chang Houn CFIs, whereas seven were found in the Trapang Rapov CFI. Relative species richness in quadrats differed between these however, with the highest occurring in Preaek Tnaot (seven species) and lowest in Trapang Ropov (three species). Seagrasses primarily occurred in monospecific patches though some mixed-species patches were observed, particularly in the Trapang Ropov CFI. Future research could evaluate whether edge effects influence the species composition of seagrass meadows. For instance, Statton *et al*. (2015) found higher herbivory rates occurred at the edges of seagrass meadows compared to areas inside the meadows, with possible indirect effects on seagrass structure.

We found the dominant species in quadrats across the three CFIs were *T. hemprichii* and *C. rotundata*, whereas the least common was *H. pinifolia,* and *H. ovalis* was only observed outside of quadrats. This is consistent with other surveys in Kampot and Kep which identified *T. hemprichii* and *E. acoroides* as the dominant species (Coals *et al*., 2019; WEA & MCC, 2020) and *H. pinifolia* as the least common (Ouk *et al*., 2010). However, Supkong & Bourne (2014) found *H. pinifolia* was the third most dominant species within Kampot Province, suggesting it may be more abundant in other areas of the province. Similarly, Fauna & Flora (2024) found *H. pinifolia* was the dominant species in northern Koh Kong Province, further suggesting in-country variations in relative species abundances.

As long-leaved seagrasses, *E. acoroides* and *T. hemprichii* are well adapted to turbid waters in which their leaves can extend towards sunlight to maximise photosynthesis (Supkong & Bourne, 2014). These larger seagrass species outcompete smaller, opportunistic and pioneer species such as *H. ovalis*, *S. isoetifolium*, *H. uninervis* and *C. rotundata* (Moreira-Saporiti *et al*., 2021). Further, *T. hemprichii* can dominate intertidal zones due to its higher tolerance to air exposure (Lan *et al*., 2005). Following disturbance however, pioneer and faster-growing species such as *Halophila* spp. may outcompete slower-growing taxa such as *T. hemprichii* (WEA & MCC, 2020). The abundance of *E. acoroides* and *T. hemprichii* in our study sites may suggest the seagrass meadow in shallow areas of the three CFIs are relatively well protected from disturbance including illegal bottom-trawling. Conversely, the presence of eight species comprising a mix of fast- and slow-growing species, could indicate that persistent disturbance has maintained the multi-species meadow. As such, further studies are needed to understand the factors influencing the species composition of local seagrass assemblages.

The relative abundance of seagrasses was highest in Preaek Tnaot (46.5%), followed by Chang Houn (42.5%) and Trapang Ropov (28.2%). Based on Supkong & Bourne (2014) who considered coverage values of 25–50 % to indicate moderate seagrass health, the seagrass meadows of our three CFIs are moderately healthy. Similarly, Supkong & Bourne (2014) regarded seagrasses in an area overlapping with our study site (including intertidal zones extending from Trapang Ropov to Chang Houn CFI) as moderately healthy. Water depth influences seagrass abundance (Longstaff & Dennison, 1999; Ouk *et al*., 2010) and other studies have documented higher seagrass coverage in shallow, intertidal waters in Kampot Province (Fauna & Flora, 2024).

Benthic and epiphytic algae were most abundant in the Preaek Tnaot and Chang Houn CFIs. This is consistent with previous research showing a positive correlation between seagrass and algae abundance in the Kep Archipelago (Coals *et al*., 2019). Algae proliferation may be facilitated by the shallow, nutrient-rich and high-light conditions of our study site (Riegl *et al*., 2005). Water depth is crucial for understanding the distribution of macrophyte assemblages (Le Fur *et al*., 2018). When algal blooms occur, seagrass beds suffer directly from competition for resources and reduced living space (Han & Liu, 2014). Coastal pollution such as garbage, indus-

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trial waste and other anthropogenic pollutants can create excess nutrients that cause eutrophication and algal blooms (FiA, 2006).

Seagrasses meadows in the three CFIs encompassed 1,488 ha, comprising 544 ha in Trapang Ropov, 756 ha in Preaek Tnaot and 188 ha in Chang Houn. These data suggest seagrass cover within the CFIs has shifted since surveys in 2011 (FiA, 2011c). More specifically, our data suggest seagrass cover in Trapang Ropov increased by ca. 42% (from 315 ha: FiA, 2011c), whereas cover in Chang Houn declined 53% (from 400 ha: FiA, 2011a). The latter is primarily due to land reclamation for port development in the Chang Houn CFI (Fig. 4) and may also have been exacerbated by dredging activity, which can prevent seagrass growth by reducing water quality (Di Carlo & McKenzie, 2011). Water turbidity was evident throughout our study site, with sediments and algae accumulating on seagrass leaves, particularly near the development area in the Chang Houn CFI. Several studies have found trawling and coastal development increases sedimentation and reduces light penetration, thereby affecting seagrass (de Groot, 1984; Muhando & Rumisha, 2008; Sharma, 2009).

We found seagrasses in our CFIs occurred at water depths ranging from 0.5 m to 4 m. This is consistent with WEA & MCC (2020), who recorded them in water depths between 0.7 m and 3.8 m, with most present in water depths less than 2.6 m. Similarly, Fauna & Flora (2024) and FiA (2023a) found most seagrasses in Cambodia occurred in waters less than two metres depth, although Ouk *et al*. (2010) recorded seagrasses up to seven metres depth in Kampot. The absence of seagrass at depths greater than 4 m in our study could be the result of illegal bottom trawling which was observed in and around our sites. Similarly, WEA & MCC (2020) documented trawling vessels and their paths on the ocean floor during surveys in the three CFIs, where seagrass presence was largely confined to shallow waters inaccessible to trawling vessels and areas protected by concrete poles. Supkong & Bourne (2014) also identified destructive fishing practices including trawling as a primary threat to seagrass in Kampot Province.

Despite environmental pressures in the three CFIs, we found rich biodiversity within the seagrass beds including crabs, small fish, sea urchins, snails, oysters, and many other species. Seagrass provides an essential nursery and feeding habitat for a wide range of marine species (Chhoub *et al*., 2002; Hem *et al*., 2002; Di Carlo & McKenzie, 2011). Seagrass meadows are also vital to fisheries. Kaarlep (2014) found that 89% of economically valuable species caught by small-scale fishermen in Kampot Province are dependent on the seagrass ecosystem, including blue swimming crabs and several shrimp species. Further, habitat connectivity between seagrasses, coral reefs and mangroves increases fish diversity and abundance by increasing the availability of shelter and food provisioning (Unsworth *et al*., 2008). Consequently, maintaining connectivity is important for both marine biodiversity and local fisheries.

We recommend the adoption of management approaches that balance coastal development needs with seagrass protection in Kampot Province. These could include the formal establishment of a Marine Fisheries Management Area to enhance existing co-management efforts by the CFIs and Fisheries Administration. To the same end, rigorous environmental impact assessments should be undertaken prior to coastal development projects to mitigate negative effects on seagrass meadows. Additionally, specific planning is needed to designate areas for marine conservation and development. Tools for seagrass protection and monitoring may include research, designation of protected zones, community co-management, deployment of anti-trawling structures, and consideration of blue carbon stored in seagrass areas. Finally, we reiterate the important role that CFIs play in managing and safeguarding seagrass habitats in Cambodia. These promote marine conservation through sustainable practices and monitoring, ensuring the long-term viability of the ecosystem for future generations (Chea *et al*., 2014).

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